Westphal.5754

UNITED STATES PATENT APPLICATION

of

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for

DOOR

DOOR

BACKGROUND OF THE INVENTION

The present invention relates to the field of loudspeakers, and in particular to a door that acts as a radiant acoustical structure.

U.S. Patent 3,247,925 discloses a flat panel loudspeaker, which has a multimodal resonance radiator element formed by two films between which is arranged a core consisting of high resistance foam or a core with a honeycomb structure. This radiator is driven by electrodynamic transducers that excite the radiator to multimodal resonance in accordance with a fed-in electrical audio signal to yield a corresponding acoustic audio signal.

U.S. Patent 3,247,925 describes a woofer having an electromagnet disposed on the floor of its cubical housing. A flat, first diaphragm fastened on the housing like an intermediate ceiling is seated on this electromagnet. The housing ceiling is formed by a second flat diaphragm, which is mechanically connected to the flat first diaphragm by a column that includes several honeycomb-shaped columns to transmit soundwaves.

A motor-vehicle door capable of housing electrical equipment is disclosed in the published German application DE 196 54 956 A1. The motor-vehicle door accommodates an electrical drive to move the outside mirror, an electrical drive to raise and lower the window, and a relatively large loudspeaker to radiate sound. To supply the electrical equipment with electrical current and to control this equipment by electrical control signals, electric contacts are situated at the door lock of the motor vehicle door. When the door is closed, these are connected to electric contacts that are situated on a closure element, which is disposed on the car body and positively engages the door

lock. One disadvantage of this motor vehicle door is that a relatively large loudspeaker must be built into the door to radiate sound.

Therefore, there is a need for a door that includes structural components configured to radiate acoustical energy.

SUMMARY OF THE INVENTION

Sub a1

Briefly, according to the present invention, a door leaf includes a stiff, light structural part that maintains fed-in vibrational energy and, by flexural waves, propagates this energy in at least one active surface perpendicular to its thickness to distribute resonance mode vibration components over at least one surface, which has specified, preferred locations or sites within it for transducer devices, which are affixed on the structural part at one of the locations or sites to set the structural part into vibration and to allow it to resonate, thus creating an acoustic radiator that delivers an acoustic output signal when it vibrates in resonance, the front and/or the rear cover panel of the door leaf being part of the stiff, light structural component. The transducer(s) is/are situated between the cover panels. This arrangement provides a door with a loudspeaker function, which needs no extra volume compared to an ordinary door, and which is able to provide sound reliably and comprehensively to one or more rooms, which adjoin this door acting as a loudspeaker. Advantageously, additional loudspeakers or loudspeaker boxes are not required in a room that receives sound by this door with loudspeakers.

In a preferred embodiment of the invention, the signal is supplied through an electrical connection via the hinge. It is thus possible to maintain the loudspeaker function of the door leaf at every opening angle, since there exists a secure connection from the signal source, via the hinge, to

the transducer that is situated in the door leaf. This assumes the usual arrangement, in which the signal source, for example the stereo system with an amplifier, is situated outside the door.

It has proven especially advantageous to provide a switching element that detects the open state of the door leaf and interrupts transmission of the signal through the hinge to the transducer when the door is open, and allows signal transmission when the door is closed. An optimized and specified sound irradiation with a specific directional characteristic is thus provided in relatively simple fashion.

According to another preferred development of the invention, the signal is conducted over corresponding contacts on the door leaf and the frame. This special arrangement of the contacts on the door leaf and on the frame ensures that contact is made only when the door is closed, so that no additional switching element is needed to achieve the desired, preferred acoustic irradiation.

In a preferred embodiment, several drivers (e.g., electrodynamic and/or piezoelectric drivers) are used as transducers to drive the stiff, light structural part with the front and/or rear cover panel. The plurality of transducers and their optimized arrangement on the structural part and also the choice of different types of transducers make it possible to create an optimized acoustic radiator that has good acoustic reproduction properties over a broad frequency range. In particular, the various transducers have applied to them an electrical acoustic signal, after this signal has been frequency-divided by a frequency-dividing network. This makes it possible to optimize the signal infeed, the disposition of the transducers, and the electrical signal supplied to the transducers.

According to an especially preferred design of the invention, flexible, damping support elements are situated between the cover panels with the two structural components that individually or jointly are excited to multimodal resonances. These elements on the one hand make it possible to

stiffen the door leaf and the light components against one another, and on the other hand they prevent transmission of the vibrations (e.g., from the structural part with the front cover panel to the other structural part with the rear cover panel). This decouples the front and rear cover panels from the light structural components. With two such light structural parts, a front and a rear cover panel, it is possible to feed one kind of music into one room, which is separated from another room by the door, while another type of audio signal is fed into this other room. This acoustic separation achieves an especially high degree if care is taken to make the door sufficiently stable.

According to another embodiment, the front and rear cover panels are connected by an acoustic sandwich core, preferably including a Nomex honeycomb structure, an aluminum honeycomb structure or high resistance foam. Together they form a stiff, light structural component capable of multimode resonance. This arrangement is also called an acoustic sandwich. The acoustic sandwich core preferably has one or more recesses, which contain one or more transducers. These excite the structural component containing the front and rear cover panels and the acoustic sandwich core to flexural vibrations and thus make it possible to feed sounds into the rooms which adjoin the door. Furthermore, the door leaf that acts as a loudspeaker proves to be especially stiff with a simple and durable structure. Nevertheless, this door leaf is light, since the acoustic sandwich core has a relatively low density.

A special advantage of a door acting as a loudspeaker is that the adjoining masonry prevents an acoustic short circuit.

Preferred transducers are electrodynamic inertial vibration drivers, which directly excite the structural component to multimodal vibrations and thus turn this structural component into an acoustic radiator. These inertial vibration drivers are especially suited for such loudspeakers.

The front and/or rear cover panels may include a surface structure formed by a single-layer or a multi-layer criss-cross veneer, especially one of pinewood. This surface design on the one hand imparts to the structural part the stiffness that is necessary for this part to have the property of a multimodal radiator, and, on the other hand, the door that acts as a loudspeaker is thus given the appealing visual appearance of a wooden door. This especially encourages acceptance of this type of door.

It has proven especially advantageous to divide the front and/or the rear cover panel into various zones, which are equipped with appropriate structural parts capable of flexural vibrations and acting as multimodal acoustic radiators. The various zones of the front cover and/or the rear cover can thus be designed with different acoustic properties, significantly improving the acoustic experience from the loudspeaker door. For example, this design makes it possible to design one zone as woofer and another zone as tweeter. In corresponding fashion, one zone can be designed as the right speaker and another zone as the left speaker, and can be driven as such. The electronics needed to separate the corresponding signals, for example a frequency-dividing network or a channel-separating stage, preferably are disposed in the interior of the door leaf. This greatly simplifies the signal infeed, since only a single, complete signal needs to be fed in for all the zones of the door. This is preferably affected through the door hinge.

According to yet another embodiment, the loudspeaker door has one or more bass reflex openings. The bass reflex openings preferably are disposed in the door leaf in the area of the transducers or the electronic components to provide cooling of these components by air circulation through the bass reflex openings. This ensures reliable cooling of the loudspeakers, which are subject to heating during operation, thus substantially increasing their useful life and reducing their

failure rate. In particular, such bass reflex openings make it possible to accommodate in the door leaf not only frequency-dividing networks but also active components such as amplifier stages. This is made possible in an especially advantageous manner by an arrangement of several transducers with several bass reflex openings.

Sub A2

In a preferred design of the invention, the front and/or rear cover panels, with the stiff, light structural part, have a clamping device that makes it possible to tension the stiff, light structural component with a view to changing and improving the acoustic properties of the stiff, light structural component. The clamping device here surrounds the light structural component and transfers the tension from the frame of the door leaf, through the relevant cover panels, to the light structural component.

The present invention is not only suited for room doors, but also for cabinet doors, where the door leaf is not mounted on a hinge but is pivotally mounted in the body of a piece of furniture.

These and other objects, features and advantages of the present invention will become apparent in light of the following detailed description of preferred embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a first embodiment of the inventive door leaf, partially in section;

FIG. 2 illustrates a second embodiment of the inventive door leaf, partially in section; and

FIG. 3 illustrates a third embodiment of the inventive door leaf, partially in section.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates, partially in section, a segment of a door leaf 1 that acts as a loudspeaker. The door leaf 1 has a frame 2 with a front and a rear cover panel 3 and 4. The frame 2 and the front and the rear cover panel 3 and 4 bound an interior space 6 of the door leaf 1. An acoustic sandwich core 5 of highly resistant foam is disposed within the interior space 6 and extends from the front cover panel 3 to the rear cover panel 4. The front cover panel 3, the acoustic sandwich core 5, and the rear cover panel 4 form a stiff, light structural part, which may be excited to flexural vibrations in such a way that it acts as a multimodal resonance radiator and delivers an acoustic output signal when it vibrates in resonance.

The acoustic sandwich core 5 has a recess 12, which is occupied by a transducer 8. When excited by an electric acoustic signal, the transducer excites the acoustic sandwich core 5, together with the adjoining cover panels 3 and 4, to flexural vibrations. The transducer 8 is designed as an electrodynamic inertial vibration driver. The front cover panel 3 contains a clamping device 10, including a diaphragm and situated between the acoustic sandwich core 5 and the frame 2. The clamping device keeps the front cover panel 3 under tension in the region of the acoustic sandwich core 5 to yield a favorable acoustic design. Both the front cover panel 3 and the rear cover panel 4 radiate sound. Therefore, the door leaf 1 radiates sound to the rooms on both sides. With this arrangement, the acoustic signals generated by the transducer 8 are identical on both sides of the door leaf. This type of door leaf, acting as a loudspeaker, is especially suitable for use in schools, museums, railroad stations, and similar buildings with a large number of doors, where a large number of rooms should simultaneously receive uniform announcements or other acoustic signals. In the sense of the invention, the most simple and robust door leaves should be used to act as loudspeakers.

In the interest of brevity, when describing the embodiments set forth in FIGs. 2 and 3, only the differences from the door leaf 1 of FIG. 1 will be explained below. In the drawings, the same or corresponding parts of the door leaf 1 carry the same reference symbols.

FIG. 2 illustrates a door leaf 1 whose front cover panel 3 is connected to an acoustic sandwich core 5, which is disposed in the interior space 6, but which does not touch the rear cover panel 4. A transducer 8, designed as an electrodynamic inertial vibration driver, as well as a flexible, damping support element 7, are situated between the acoustic sandwich core 5 and the rear cover panel 4. The light structural component, which comprises the acoustic sandwich core 5 and part of the front cover panel 3, is excited to flexural vibrations by the transducer 8, which allows this light structural component to become a multimode resonance radiator. The vibrations of the transducer 8 propagating in the direction of the rear cover panel 4 are intercepted and decoupled by the support element 7 so that only one side of the door leaf 1, on which the front cover panel 3 is situated, is apt to emit sound, while the other side of the door leaf 1 is not apt to emit sound.

Sub a3

The frame 2 of the door leaf 1 has a channel that provides a bass reflex opening 22. The interior space 6 of the door 1 is aerated or vented through the bass reflex opening 22. In this way, the heat generated in the transducer 8, when driving the light structural component, can be dissipated through the bass reflex opening 22. This prevents the loudspeaker components of the door leaf from being overheated, thus greatly increasing the lifetime of the door loudspeaker and preserving its acoustic properties over a long time even under extreme conditions.

Sub a4

FIG. 3 illustrates a door leaf 1 designed as a double loudspeaker. In this door leaf 1, both the front cover panel 3 and the rear cover panel 4 are each connected to an acoustic sandwich core 5, thus forming a front acoustic sandwich 3a and a rear acoustic sandwich 4a. These acoustic

sandwiches 3a, 4a are spaced apart and form the light structural component. Two electrodynamic transducers 8 are situated between them, driving the acoustic sandwich 3a, 4a respectively. These two transducers 8 are arranged back-to-back and are connected to one another through a flexible, damping support element 7. This support element 7 makes it possible to decouple the vibrations of the transducers 8 and their associated acoustic sandwiches 3a, 4a.

Sub a4

Besides the front cover panel 3, the rear cover panel 4 is also equipped with a clamping device 10, which is likewise suited to tension the region of the rear cover panel 4, which is rigidly connected to the acoustic sandwich core 5 and forms the acoustic sandwich 4a.

The door leaf 1 of FIG. 3 makes it possible to irradiate the two rooms separated by the door with different acoustic signals. This permits broad application of this door leaf 1, especially since the special design of the bass reflex opening 9 provides effective heat dissipation in combination with an advantageous improvement of the acoustics of the resulting loudspeaker.

The transducers 8 used in the embodiments of FIGs. 1 to 3 have electric signals applied to them, which are conducted to the transducer 8 via door elements which are not shown here, namely the door frame, the hinges or bands, the frame 2, the interior space 6, and, where applicable, the acoustic sandwich core 5. A frequency-dividing network to divide the electrical signals and an amplifier to amplify these electrical acoustic signals can be situated along the signal path in the frame 2, neither of these being shown here in the interest of ease of illustration.

According to another aspect of the present invention, two or more loudspeaker systems with their own drivers, acoustic sandwiches, and possibly cover panel segments can be respectively associated with one side of the door leaf, so that the door leaf at the same time forms loudspeakers for different frequency ranges, for example high frequency, medium frequency, and low frequency.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the scope and spirit of the invention.

What is claimed is:

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